Lucía Vilallonga
Professor Christoph Nolte
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Evaluating Effectiveness of Mass. Incentives in Alleviating Economic Burden of Rooftop Solar Adoption

A case study of four MA towns

ABSTRACT

Despite the well-known benefits of expanding rooftop solar adoption in residential communities, existing installations in Massachusetts are limited in number and geographic spread. This paper explores this trend through a case study of four towns: Newton, Milton, West Roxbury, and Hyde Park. Previous market research and academic studies have revealed disparities in the distribution of income tax incentives for rooftop solar installation costs, which suggests that these incentive programs alone may not be effective drivers of adoption. Comparing a control scenario to existing state and federal income tax incentives and private incentive programs shows that indeed, overall adoption is between 66% and 79% more prevalent with incentive programs than without. Furthermore, a combined incentive program that includes income tax credits and targeted discount programs not only results in the most overall adoptions, but also increases adoption among low-income households.

INTRODUCTION

The urgency of the climate crisis and its accelerating consequences necessitate a swift and decisive transition away from fossil fuels and towards more renewable energy sources. The most abundant of these sources include solar energy, which can be harvested through Photovoltaic (PV) systems. As the solar industry has grown and PV systems become less expensive, it has been said that networks of rooftop solar panels provide a “no-loss” avenue for making this energy transition, especially with the various federal, state, and private incentives available.

The reality, however, is that lower-income households are less able to take advantage of these incentives for various reasons. For example, these populations tend to pay less in absolute dollars of income tax, which limits the degree to which tax incentives can offset the cost of rooftop PV installation. As a result, despite the numerous energy- and money-saving benefits that expanding rooftop PV solar offers, these benefits tend to be concentrated in communities that already have means. More than one long-term study has found that the distribution of income tax credits towards rooftop solar adoption is skewed towards the top quintile, which receive the majority (60%) of the credits, while the bottom three income quintiles receive just 10%.[1,2] Market research by the National Renewable Energy Laboratory (NREL) also finds that economic considerations such as cost of installation and long-term money saved on electricity “are the biggest overall driver - but also the largest barrier - to solar adoption.”[3]

In the four Massachusetts towns of Newton, Milton, West Roxbury, and Hyde Park, the trends are no different. In records of existing PV systems, those towns with higher income communities tend to also have more rooftop solar installations (Figures 1 and 2). This distribution of incentives raises questions about equity, in particular energy justice, a movement that focuses on a “just transition” from fossil fuels in order to both halt the climate crisis and help to remediate existing social and economic disparities. Two dimensions of energy justice relevant to this analysis are: *energy burden*, or the expense of (renewable) energy expenditures relative to overall household income; and *energy poverty*, or lack of access to affordable (renewable) energy.[4] This analysis attempts to address both of these inequities.

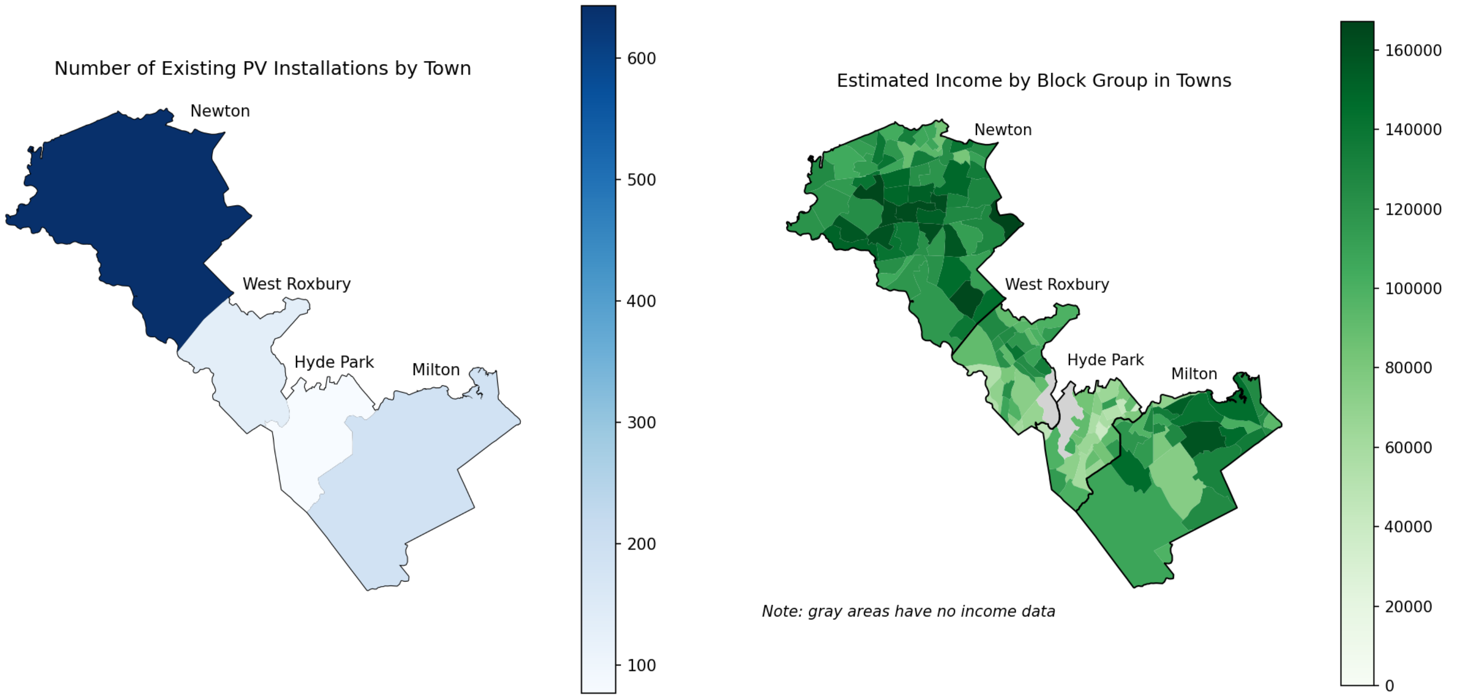

Figure 1, from left to right: Map of existing rooftop solar installations up to May 2021[5]*; map of income by block group, in 2019 USD.*[6]

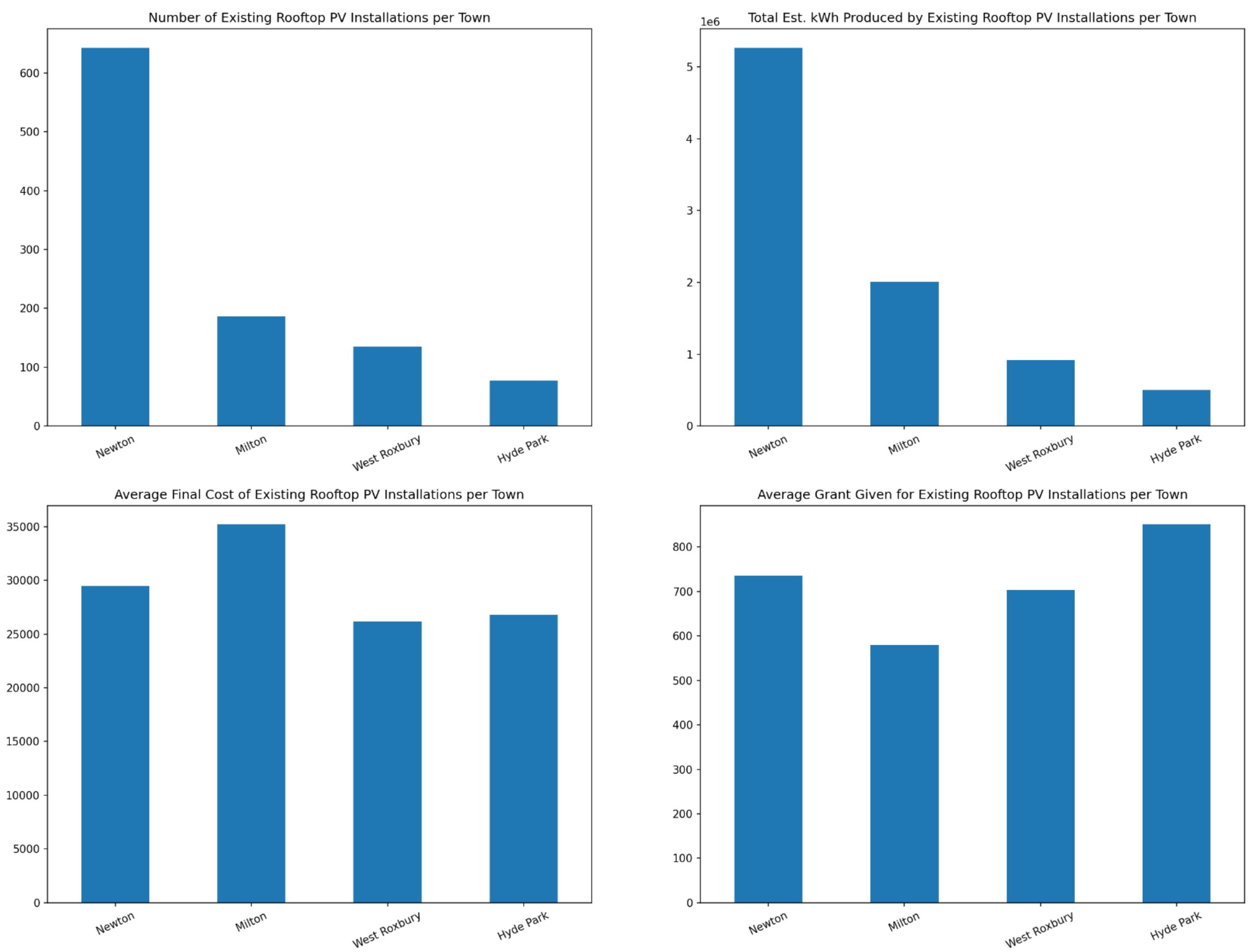

Figure 2, from top left to bottom right: histograms of the number of existing installations, total estimated kWh produced, average final cost, and average grant given in each town[5]*.*

METHODS

There are three types of solar incentives available in Massachusetts: state income tax credits, federal income tax credits, and discounts through the Solar Massachusetts Renewable Target (SMART) program (Table 1, Appendix A)[7,8,9].

Incentive Program	*Type*	*Amount*
Residential renewable energy income tax credit	State income tax credit	15% of installation costs, up to $1,000
Investment Tax Credit (ITC)	Federal income tax credit	*2006-2019:* 30% of federal income taxes
		2020-2022: 26% of federal income taxes
		2023: 22% of federal income taxes
		2024: 0% of federal income taxes (program expires)
SMART	State-backed, utility-operated	Fixed rate ($/kWh produced) over 10 years; Capped at 170.254 MW[1]

Table 1: Summary of solar installation incentives available in Massachusetts.

The various incentive scenarios analyzed are in the following groupings, and the outcome variables used to compare each scenario are described in Table 2.

1. Control: no incentives available
2. State and federal income tax incentives only
    a. 2006-2019
    b. 2020-2022
    c. 2023
    d. 2024
3. SMART program incentives only
    a. Random allocation of credits
    b. Cheapest-first allocation of credits
    c. Optimal allocation of credits (to minimize $ paid per kWh produced)
    d. Low-income priority allocation of credits[2]
4. Both income tax and SMART program incentives, using 2006-2019 federal tax credit values
    a. Random allocation of credits
    b. Cheapest-first allocation of credits
    c. Optimal allocation of credits (to minimize $ paid per kWh produced)
    d. Low-income priority allocation of credits

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[1] See Appendix A for table of rate values, which are income- and capacity-dependent, and an explanation of the cap value used, which also varies by utility

[2] "Low income" in the SMART program is defined as a household making 65% or less than the average income of Massachusetts.[10,11]

Variable Name	*Description*
N	Total number of new installations across all towns
nNewton	Number of new installations in Newton
nMilton	Number of new installations in Milton
nWestRoxbury	Number of new installations in West Roxbury
nHydePark	Number of new installations in Hyde Park
area_km^2	Total area of solar panels installed
MW	Estimated total MW of electricity generated
avoidedMTCO_2e	Estimated avoided emissions from generating electricity with rooftop solar vs. the Massachusetts grid
costForMA	Total value of state tax credits towards the new installations
costForFed	Total value of federal tax credits towards the new installations
totalBudget	Total credits paid through all programs
costForIndividuals	Estimated total cost of the new installations for households
avgCostForIndividuals	Estimated mean cost of the new installations for households
meanIncome	Estimated mean income of households with new installations
incomePercentileRange	Estimated percentile ranges for income of households with new installations

Table 2: Summary of outcome variables

Assumptions

Since this analysis focuses on the economic viability of rooftop PV installations in towns of Massachusetts, it is assumed that the single barrier to adoption is the cost of installation. Of course, this assumption ignores all the political, social, and personal reasons for adopting or not adopting rooftop solar. In fact, factors such as family size, mortgage, roof material, and the prevalence of rooftop PV adoption in one's neighborhood have been found to be significant predictors of solar adoption, in addition to economic reasons (Figures 3 and 4).[3]

It is also assumed that: (1) all residential rooftops in the data are composed of materials that are compatible with PV installation; (2) PV installations are fixed and tilted for optimal electricity generation over the course of a year; and (3) the solar panels are not shaded by other structures or trees enough to completely obscure the sun over the course of a full day. As a result, the estimated electricity generated will vary greatly from reality.

The final assumption is that all the rooftops selected to install solar systems can reasonably connect to the Massachusetts grid at no cost to the consumer. In reality, the process is much more complicated, and can vary by utility company.[12]

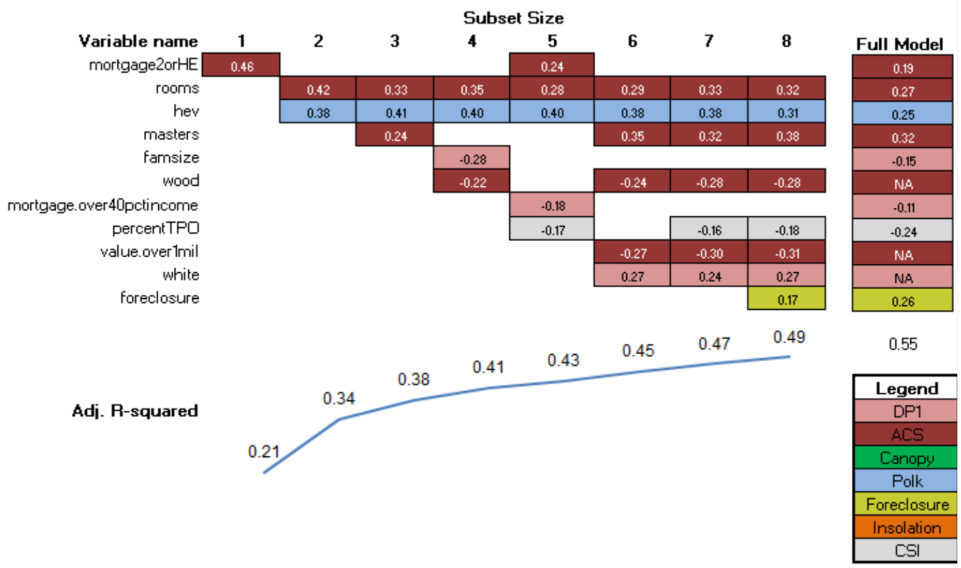
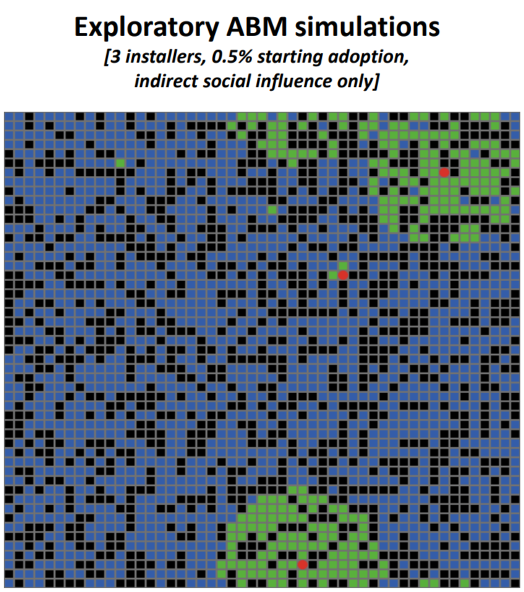


Figure 3: Modeled predictors of rooftop solar adoption and their respective Adj. R^2 values. Mortgage variables alone are not strong predictors of adoption. Source: NREL SEEDS study.[3]



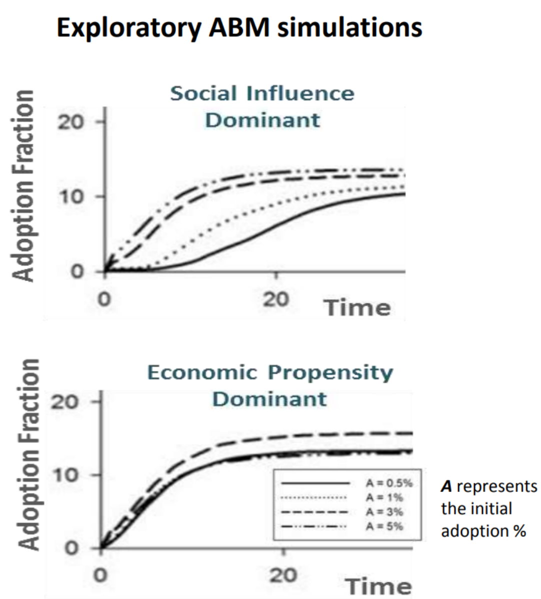


Figure 4: Rooftop solar adoption simulated in a community to explore both social and economic factors. On the left: red dots are initial installers, green are adopters, blue are non-adopters who may adopt, and black dots are non-adopters who will not adopt. Note that the dots neighboring installers (red) are more likely to adopt (green) or become adopters (blue). The graphs on the right show that simulations with social influence as the dominant variables, such as that on the left, had similar adoption fraction result as those of economic simulations, suggesting that economics alone do not account for all rooftop solar adoption decisions. Furthermore, the social influence is stronger in simulations with the highest initial adoption percentage, suggesting that social influences are stronger if many people in a community adopt solar at the same time, and their neighbors may follow. Source: NREL SEEDS study.[3]

Calculations

Model calculations are summarized in Table 3.

Variable	*Value(s) Used in Analysis*	*Source(s)*
Residential rooftop polygons in the study locations	Roofprint polygons in all of Massachusetts, filtered by location to include only **Newton, Milton, West Roxbury,** and **Hyde Park** Massachusetts tax parcel polygons, filtered to include only residential and mixed-use mostly residential polygons Used vector intersection of the above polygon layers in QGIS to filter residential roofprints	MassGIS[13]
Area available per rooftop	Total roofprint area in ft^2	
Town of each rooftop	Town polygons spatially joined with roofprint polygons	
Annual electricity generation potential per rooftop	Electricity generation potential per 1 kW PV system per day = **PVOUT (kWh/day)** (Figure 5). These data assume a total loss of **11%** from soiling and conversion. Estimate each 1 kW system as being composed of **320-Watt** panels; divide available area of roofprint by area of these panels (**~17.5 ft^2**) to get total number of panels on each rooftop Multiply electricity generation potential by the total capacity of the system: (X kW/1 kW) * PVOUT * 365 days = **potentkWh/year**	SolarGIS[14] ShopSolarKits[15]
Available sunlight hours per year	2,739 hours	ClimateMPS[16]
kW generated per rooftop per year	Divide electricity generation potential per year by sunlight hours per year: potentkWh/year * 2,739 = **kW/year**	
Household income per rooftop	Average income in 2015-2019 per block group, reported as number (**n**) reported within each range (**AB_i**, A<B). Block groups given as polygons. Spatially joined block group polygons with roofprint polygons, then computed weighted average income values for each roofprint: **wAvgInc_l** = lower range limit (A_i) weighted by number reported at each range (n_i): wAvgInc_l = $\frac{\sum A_i n_i}{\sum n_i}$ **wAvgInc_u** = upper range limit (B_i) weighted by number reported at each range (n_i): wAvgInc_u = $\frac{\sum B_i n_i}{\sum n_i}$ wAvgInc_l was ultimately used for all analysis. See Appendix B for the reported income ranges.	NHGIS[6]
State income taxes per rooftop	MA income tax rate (**5%**), multiplied by wAvgInc_l = **estStateIncT**	Tax Foundation[17]
Federal income taxes per rooftop	2019 tax rate by bracket, multiplied by wAvgInc_l = **estFedIncT**	CreditKarma[18]

Emissions avoided by each rooftop PV system, in $MTCO_2e$	2019 eGRID emissions estimate for electricity generated in Massachusetts = **780.6 $lbCO_2$/MWh** Convert kWh generation potential to MWh: potentkWh/year * 1000 = **potentMWh/year** Multiply potentMWh/year by emission rate: potentMWh/year * 780.6 = **emAvo_lbsCo$_2$e/year** Convert emissions to $MTCO_2e$/year: emAvo_lbsCO$_2$e/year * **2205 $MTCO_2e/lbCO_2e$** = **emAvo_MTCO$_2$e/year**	US EPA[19] MetricConversions[20]
Cost of PV system per kW generated	National average cost = **~$3.04/kW** Multiply by **kW/year** to get **PVcostEst**. Note: since this is an estimate of installation costs, which are one-time payments, ignore the /year denominator. The denominator would be used to calculate long-term energy savings and net-metering benefits, which are outside the scope of this case study.	EnergySage[21]

Table 3: Summary of calculations and assumptions made.

Finally, the "affordability" of a PV system was determined as a ratio of the estimated cost of installation after incentives, if any, vs the estimated income. Using existing installations data, a threshold for the study locations was found to be **28%**. That is, a household would adopt rooftop solar if the cost of the system was 28% or less of their income.

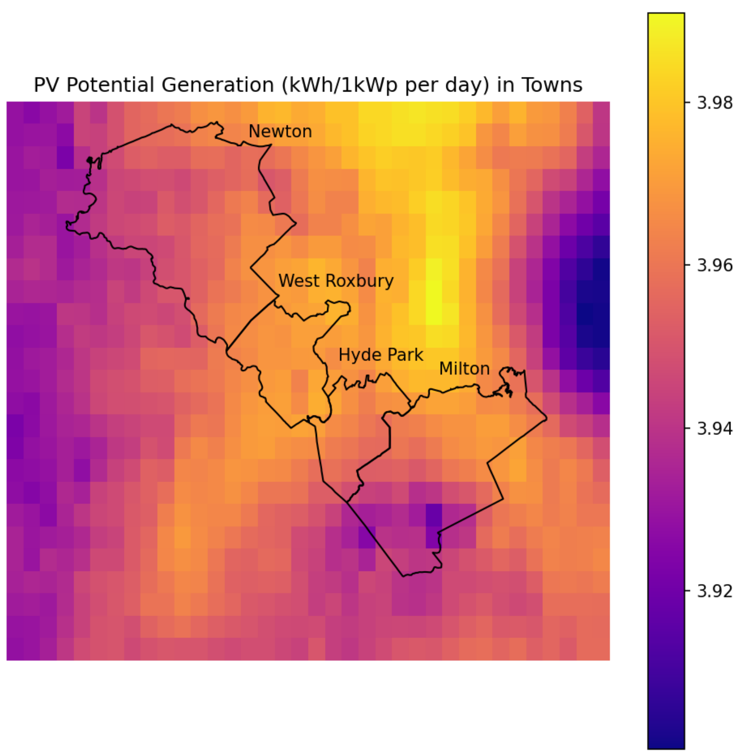


Figure 5: Electricity generation potential, expressed in kWh produced by a 1 kW solar system, in the study locations.

RESULTS

The rooftop solar adoption outcomes for individual incentives (that is, tax incentives only or SMART incentives only) are summarized in Table 4.

Scen./Var.	*Control*	*Tax Incentives (2006-19)*	*Tax Incentives (2020-22)*	*Tax Incentives (2023)*	*Tax Incentives (2024)*	*SMART: Random Allocation*	*SMART: Cheapest Priority*	*SMART: Optimal Allocation*	*SMART: Low-inc. Priority*
N	26,332	**43,632**	41,123	38,568	27,387	6,455	26,548	0	6,719
nNewton	10,618	**19,134**	17,873	16,558	11,130	2,764	9,288	0	402
nMilton	5,484	**8,356**	7,978	7,613	5,668	1,297	5,072	0	553
n West Roxbury	5,903	**9,208**	8,736	8,296	6,116	1,346	6,664	0	1,893
n Hyde Park	4,327	**6,934**	6,536	6,101	4,473	1,048	5,524	0	3,871
area (km^2)	1.49	**3.72**	3.36	2.99	1.6	0.48	1.43	0	0.27
MW	154.36	**386.54**	348.52	310.96	166.41	170.24	170.24	0	170.25
*avoided $MTCO_2e$ **	149.7k	**374.8k**	337.9k	301.5k	161.4k	48.5k	143.8k	0	27.3k
*cost for MA ($) ***	**0**	37.5 M	35.4 M	33.2 M	**23.5 M**	0	0	0	0
*cost for Fed. Govt. ($) ***	**0**	352.5 M	275.5 M	**208.0 M**	0	0	0	0	0
*total budget ***	**0**	390.0 M	310.9 M	241. 2 M	23.5 M	31.4 M	93.1 M	0	**17.7 M**
*total cost for adopters ($) ***	469.3 M	1,137.6 M	1,024.1 M	912.1 M	482.4 M	120.8 M	357.7 M	0	**68 M**
mean cost for adopters ($)	17,821.09	26,072.42	24,903.22	23,648.84	17,612.43	18,707.90	13,472.28	0	**10,117.16**
mean income of adopters ($)	118,973.31	119,151.24	119,375.89	119,454.29	119,106.03	119,553.84	113,070.49	0	79,329.14
income percentile range	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0	0.05 - 23.93

** Values rounded to nearest 100 for brevity (see GitHub (Appendix C) for exact values)*

*** Values rounded to nearest 100,000 for brevity*

Table 4: Summary of adoption outcomes in study locations under control, state and federal tax incentives, and SMART incentives individually.

Optimal allocation, in this case prioritizing SMART payments to households with the lowest $/MW produced, is not possible. This is because the set of cheapest per Mega-Watt systems that are affordable to the owners exceed the program cap of 170.254 MW.

Note that the “best” incentive program which maximizes adoption and emissions is the 2006-2019 state and federal tax incentives (Figure 6). This comes as no surprise, given that the federal credit in these years is the greatest (30% vs 26%, 22%, and then nothing in 2024), and that the SMART incentives have a total generation cap of 170.245 MW, which limits their effectiveness as a standalone program.

On the other hand, the program that minimizes the cost for individuals is SMART incentives with low-income priority. This suggests that tax incentives alone may not be enough to expand rooftop PV adoption in low-income households, perhaps because these populations do not have enough of a “tax burden” to significantly offset the costs of installation with income tax credit programs. This disparity will be explored further in the next round of analysis (i.e. Table 5).

As expected, minimal costs for the state and federal government come from having no incentives at all (i.e. control) or only state incentives (i.e. 2024). Clearly, expanding solar adoption will take some investment from the state, especially to achieve more adoption among lower-income households.

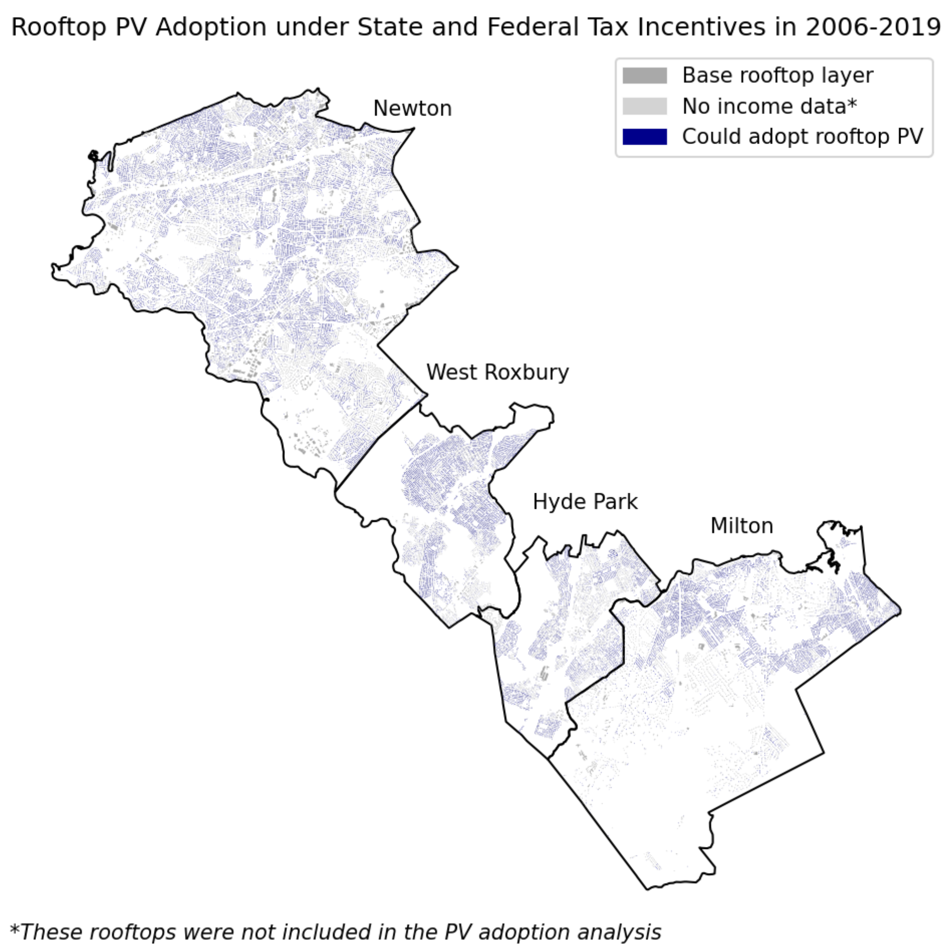


Figure 6: Map of adoption outcomes under state and federal tax incentives in 2006-2019 only. In this scenario, there is widespread adoption across all study locations, but adoption is still not evenly distributed.

Given that the state and federal tax incentives in 2006-2019 are the most successful at minimizing costs and maximizing electricity generation and emissions avoided, these were combined with the SMART incentives to see how the outcomes change (Table 5).

In this case, lower values of mean and total costs for adopters can be misleading, because the scenario with the minimum values (the control) also has the least total number of adopters, the least electricity generated, and the highest average income of adopters. This may be because, without incentives, only higher-income households can afford to install rooftop solar systems. Additionally, the cost/income adoption threshold of 28% may be enforcing an artificial "system size cap," since the cost estimation is based on kW capacity, which is partially tied to the system's area. All of this would result in households with a combination of smaller roofs and higher incomes adopting at cheaper average prices than otherwise occurs when incentives are available. This is borne out in the outcome visualization for the control scenario (Figure 7).

Compared to the control, where the majority of new adoptions occur in Newton, the low-income priority allocation of SMART credits program shows relatively few adoptions in Newton and Milton and many more in West Roxbury and Hyde Park (Figure 8). Town-by-town comparisons between the control, 2006-2019 tax incentives, and combined incentives program can be found on this project's GitHub page (Appendix C).

Scen./Var.	*Control*	*Tax Incentives (2006-19) plus SMART: Random Allocation*	*Tax Incentives (2006-19) plus SMART: Cheapest Priority*	*Tax Incentives (2006-19) plus SMART: Optimal Allocation*	*Tax Incentives (2006-19) plus SMART: Low-inc. Priority*
N	26,332	45,555	44,467	43,769	**47,065**
nNewton	10,618	**20,131**	19,125	19,284	19,488
nMilton	5,484	8,607	8,418	8,360	**8,629**
n West Roxbury	5,903	9,560	9,591	9,193	**10,467**
n Hyde Park	4,327	7,257	7,333	6,932	**8,481**
area (km^2)	1.49	4.05	3.8	3.76	**4.15**
MW	154.36	937.2	640.18	**937.46**	**937.46**
*avoided $MTCO_2e$ **	149.7k	407.5k	383.0k	378.8k	**417.5k**
*cost for MA ($) ***	**0**	39.1 M	37.9 M	**37.6 M**	39.5 M
*cost for Fed. Govt. ($) ***	**0**	383.3 M	360.3 M	**356.2 M**	392.7 M
*total budget ***	0	685.9 M	646.2 M	638.5 M	702.6 M
*total cost for adopters ($) ***	**469.3 M**	930.6 M	1,013.5 M	792.1 M	910.3 M
mean cost for adopters ($)	**17,821.09**	20,428.91	22,792.92	18,097.51	19,340.37

mean income of adopters ($)	118,973.31	118,798.78	118,142.46	119,311.36	116,231.02
income percentile range	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76

** Values rounded to nearest 100 for brevity (see GitHub (Appendix C) for exact values)*
*** Values rounded to nearest 100,000 for brevity*

Table 5: Summary of adoption outcomes in study locations under control and combined state and federal tax and SMART incentives.

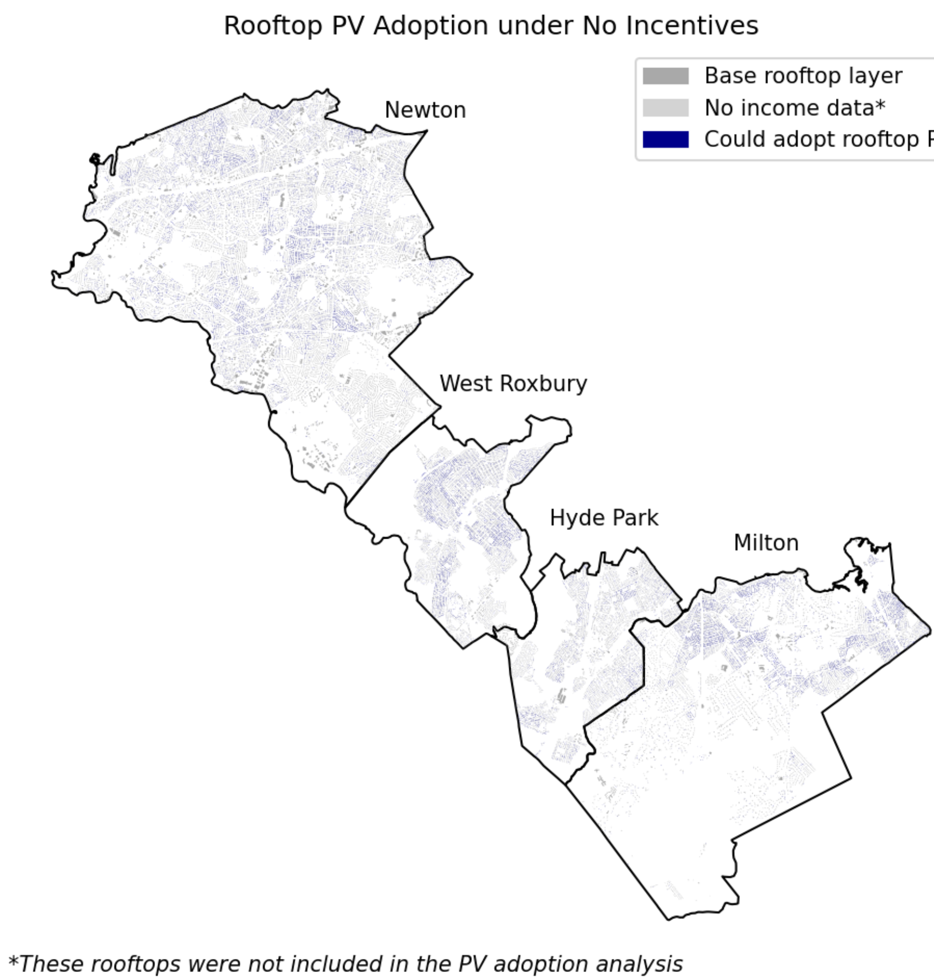


Figure 7: Map of rooftop PV adoption under the control scenario, wherein no incentives are available. Note the density of blue polygons (new adoptions) in Newton, which has the highest average income of each of the four study locations.

Finally, compare the "best" standalone incentives program to the "best" combined incentives program, and to the control (Table 6). By almost every measure, the combined 2006-2019 state and federal tax incentives plus SMART incentives allocated with a low-income priority is a great improvement over both the control scenario and the standalone 2006-2019 tax incentive programs. For example, there are 47,065 new adoptions under this scenario, compared to 43,632 in the 2006-2019 tax incentives program alone, and 26,332 under the control scenario. The combined incentives program also maximizes the number of new adoptions in each study location, which suggests that it is more effective at lowering the costs for lower-income households, without discouraging higher-income households. In contrast to the SMART incentives alone, once the 170.254 MW cap is reached, households that are not prioritized as low-income can still take advantage of the state and federal tax credits, which tend to benefit these communities more regardless.

The mean cost for adopters under the combined incentive program increases slightly with respect to the control ($19,340.37 vs $17,821.09), but this could be because the SMART incentives prioritize low-income households, and after the cap is reached, the cost of adoption is higher with just the tax incentives, but still affordable according to the adoption threshold found. The total cost similarly increases, but this is misleading because there are also many more adopters in the combined incentive scenario than in the control, which could be inflating the sum. Interestingly, the mean income of adopters under the combined program decreases, which is likely because of increased adoption by lower-income households with the priority criterion.

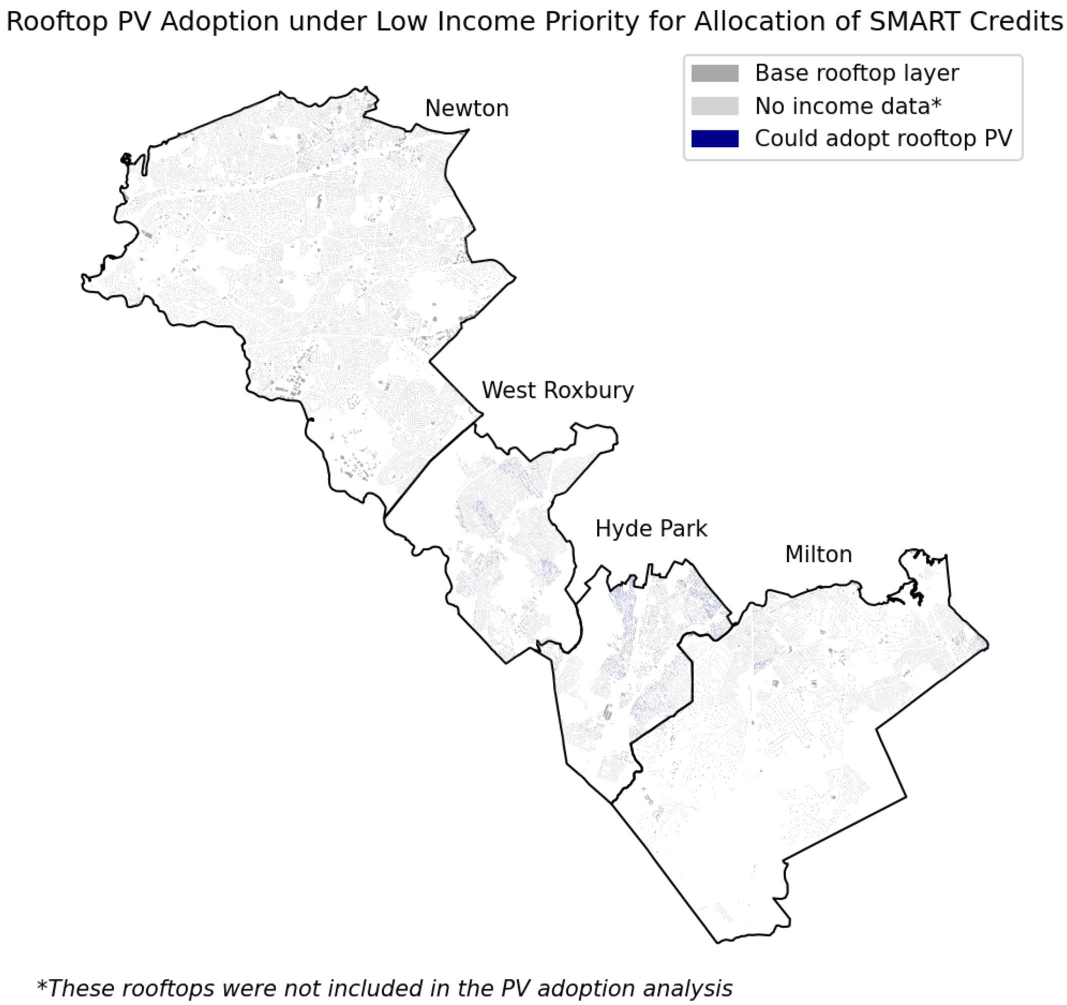


Figure 8: Map of rooftop PV adoption under only the SMART program incentives with low-income priority allocation of credits. Note that much of the blue (new adopters under this program) is concentrated in West Roxbury and Hyde Park, as well as some small areas of Newton and Milton. This is in stark contrast to the vast swathes of blue in other maps, where new adoptions in Newton and Milton dominate.

Scen./Var.	*Control*	*Tax Incentives (2006-19)*	*Tax Incentives (2006-19) plus SMART: Low-inc. Priority*
N	26,332	43,632	**47,065**
nNewton	10,618	19,134	**19,488**
nMilton	5,484	8,356	**8,629**
n West Roxbury	5,903	9,208	**10,467**
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*cost for Fed. Govt. ($) ***	**0**	**352.5 M**	392.7 M
total budget	**0**	**390 M**	702.6 M
*total cost for adopters ($) ***	**469.3 M**	1,137.6 M	910.3 M
mean cost for adopters ($)	**17,821.09**	26,072.42	19,340.37
mean income of adopters ($)	118,973.31	119,151.24	116,231.02
income percentile range	0.05 - 99.76	0.05 - 99.76	0.05 - 99.76

** Values rounded to nearest 100 for brevity (see GitHub (Appendix C) for exact values)*
*** Values rounded to nearest 100,000 for brevity*

Table 6: Summary of "best" incentive programs compared to control.

DISCUSSION

The results of this case study are consistent with prior research on the relative availability of income tax incentives for rooftop solar adoption between low- and high-income groups. This presents the state of Massachusetts, the federal government, and other stakeholders in the renewable energy transition with reasons for expanding the types and allocations of incentives offered.

For example, the Investment Tax Credit (ITC), or federal income tax credit for residential renewable energy adoption, should be renewed after 2023, and ideally at the 30% credit level. The 22% and 26% credits, while not insignificant, are simply not as effective at expanding rooftop solar adoption (Table 4). Furthermore, special attention should be paid to who benefits from private incentive programs such as SMART. Combined with income tax credits, low-income priority allocation of SMART discounts result in the greatest number of adoptions and greatly expand adoptions among low-income households (Tables 4, 5, 6). There are several ways to implement this in practice. For example, a combination of: greater outreach in lower-income communities about the potential cost savings and benefits of rooftop solar adoption; screening applications to the SMART program for income level; and/or the creation of a separate application process, with a portion of the program's funds allocated exclusively towards low-income applications. There are barriers to these strategies too, however: due to the historically predatory practices of both some utility companies and government officials towards marginalized groups, any outreach or targeted application program may also need to overcome the resulting low levels of trust towards these insitutions.[22]

The most successful incentive program, which combines state and federal income tax incentives with low-income priority allocation of SMART benefits, comes with the greatest price tag of all the options analyzed: $702.6 million total, $39.5 million of which is absorbed by the state in lost income taxes, $392.7 million of which is absorbed by the federal government, and the remainder coming from the SMART program. To put these costs into perspective, consider the Biden-Harris Administration's failed Build Back Better Act, which, if it had passed, would have set aside $555 billion towards renewable energy and clean transportation initiatives[23]. If these were evenly distributed across all 50 states, Massachusetts would receive approximately $11.1 billion. The lost state income taxes under this incentive scenario comprise just 0.36% of these allotted funds, and the total comes in at just 6.3%. On the other hand, these costs for the state, federal, and private sectors are directly tied to savings by individuals. Furthermore, the estimated emissions avoided through this program totaled over 417,500 $MTCO_2e$, or 0.57% of Massachusetts' 73,500,000 $MTCO_2e$.[24] While the total is small in comparison to the state's overall emissions, avoiding 417,500 $MTCO_2e$ is equivalent to taking approximately 90,761 cars off the road, assuming each one emits about 4.6 $MTCO_2e$ on average.[25] Ultimately, it will be up to policymakers to decide whether expanding these programs is worth the cost, but the evidence for increased access to renewable energy, alleviation of energy injustices, and decreases in greenhouse gas emissions give a strong case for doing so.

It is worth noting that each of these residential rooftop solar incentive programs includes one inherent barrier: they all require homeownership for participation. Indeed, renters in the Massachusetts area have little access to their own renewable energy sources, and little say in the utility-related decisions made by their landlords. In some cases, even energy efficiency upgrades are discouraged or prohibited, depending on the lease. For these renters, community solar may be a viable option thanks to the Massachusetts Green Communities Act of 2008, which established the state's virtual net-metering system, allowing individuals to receive bill credits from their utility for electricity generated through community-shared solar farms.[26] However, the benefits of these programs are less straightforward, and implementation eventually depends largely on the will of utility companies rather than individuals. EnergySage estimates that savings from community solar projects can be around 10-20%, which pales in comparison to the benefits provided by residential incentives.[27] As a result, community solar may not be as effective as residential solar programs at alleviating energy burden and lack of access.

In addition to expansion of incentive programs, further work should be done to link the economic and social drivers for adoption of rooftop solar panels in Massachusetts. For example, some facets that were not explored in this analysis include: political allegiances; education level; spatial relationships among adopters and considerers[3]; models of willingness to pay[28]; and other measures of economic hardship or flourishing, besides income. With so many variables and possible confounding factors, matching should be used to effectively compare outcomes between similar households across towns, instead of town-by-town comparisons, which may conceal biases. For example, NREL has found that solar adopters and considerers are very similar across qualitative measures of political stance, education level, and financial means (Figure 9).[3] What is not clear is how non-adopters may be similar or different to these individuals, and whether or how they might still be incentivized to adopt.

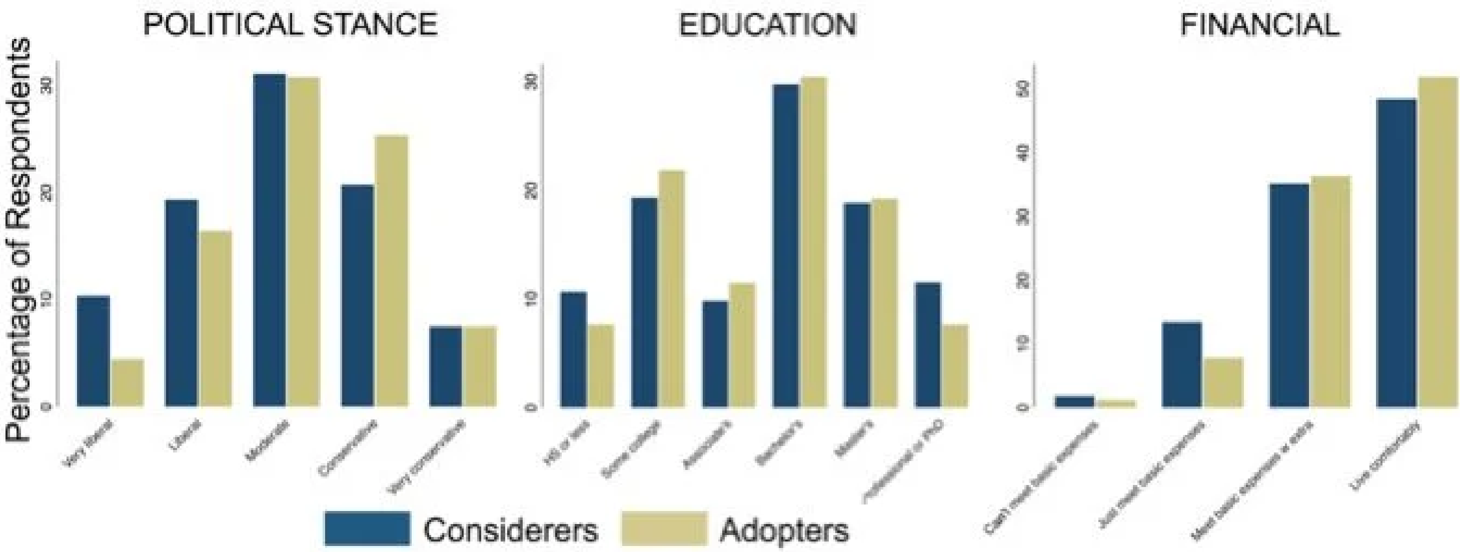

Figure 9: Bar chart showing similarities between rooftop solar adopters and considerers. Source: NREL SEEDS study.[3]

CONCLUSIONS

In the four Massachusetts towns of Newton, Milton, West Roxbury, and Hyde Park, incentives are effective drivers of rooftop solar adoption, with a naive estimate of between 66% and 79% more new installations if incentives are present than with no incentives (Table 6). The best incentive program was found to be a combination of: (1) the Massachusetts income tax credit of up to $1,000 towards installation costs; (2) the 2006-2019 federal income tax credit of 30% towards installation costs; and (3) discounts given through the SMART program, specifically implemented with a low-income priority allocation. The second-best program did not include the SMART credits, but was less effective at achieving adoption among low-income communities in the study locations.

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APPENDIX A: Summary of SMART Program Incentives

Generation Unit Capacity	*Term Length*	*Base Compensation Rate ($/kWh)*
≤25 kW (low-income)	10 years	0.26360
≤25 kW	10 years	0.22922
25 kW - 250 kW	20 years	0.17191
250 kW - 500 kW	20 years	0.14326
500 - 1000 kW	20 years	0.12607
1000 - 5000 kW	20 years	0.11461

Table 7: Base Compensation Rate in $/kWh potential electricity produced for residential rooftop PV systems applying to the SMART program, allocated according to generation unit capacity (kW) and low-income status. Note: "low-income" in this case means earning less than or equal to 65% of the mean Massachusetts income of $77,378.

APPENDIX B: Income Ranges from 2015-2019 Census Data

Low ($)	*High ($)*
0	9,9999
10,000	14,999
15,000	19,999
20,000	24,999
25,000	29,999
30,000	34,999
35,000	39,999
40,000	44,999
45,000	49,999
50,000	59,999
60,000	74,999
75,000	99,999
100,000	124,999
125,000	149,999
150,000	199,999
200,000	>200,000

Table 8: Average income ranges in 2015-2019 as reported by the Census Bureau, and combined by NHGIS with block group polygons to form income data.[6]

APPENDIX C: Project GitHub Page

URL: https://github.com/ghostpress/ma-solar
Visualizations, including town-by-town maps of incentive scenario outcomes, can be found in *output* > *viz* > *outcomes*.